The Electronic Chemist

By YVONNE LAMOREAUX, E.E.I.

It is difficult to believe that the instrument which is now so indispensable in war industry was considered just five years ago to be only a physicist's gadget. This plaything, the mass spectrometer, is able to measure quickly and accurately the masses of the constituents of many gases. A college student can learn in only a few weeks to operate the spectrometer. For this reason, and because the apparatus is able to perform in a very short time operations which are slow and tedious by other methods, the spectrometer will save many thousands of man hours. Fundamentals of the spectrometer may also be employed in the improvement of ignitron rectifiers, fluorescent lamps, or any other device that depends on a gaseous electric discharge for its operation. Westinghouse Research Laboratories have developed the mass spectrometer, largely through the work of 32-year-old Dr. John A. Hipple.

The spectrometer consists primarily of a curved glass tube, shaped into a quarter-circle. First molecules and atoms of the gas to be analyzed are bombarded with electrons at the ion source. The electrons emitted by the filament in the ion source from an electron beam by acceleration through the slits in the electrodes in the electron "gun" and form the electron beam as shown. The ions formed by the impact of the electrons on the gas molecules are accelerated electrically into the vacuum tube through a slit a hundredth of an inch wide and half an inch long and are shot toward the other end of the tube at a speed of approximately one million feet a second. An electromagnet at the curve of the tube pulls at the ions, bending them into circular paths. This principle is similar to that causing the deflection of the electron beam in the magnetic oscillograph. Ions of the desired mass going through to the other end of the tube are collected on a metal plate where they give up their charges. The charges are then amplified and counted by electric meters that indicate the number of ions of the specified weight which are contained in the mixture.

When the ions are deflected by the electromagnet, since they have a different mass the radius of curvature of the different types will not be the same. The formula $r = \frac{C}{H}\sqrt{\frac{VM}{150e}}$ represents the radius of curvature in the uniform magnetic field. Here r is expressed in centimeters, H in grams, C is the velocity of light (3×10^{10} cm. per second), V is the potential difference in volts which accelerates the ions, M is the mass in grams of the ions, and e is the electronic charge (4.8×10^{-10} e.s.u.). Since, for a given V and H, the radius of curvature depends on the ratio $\frac{M}{e}$, and since the singly charged ions are most abundant, we can limit the discussion to these and consider that the radius of curvature is dependent only on the mass of the ion.

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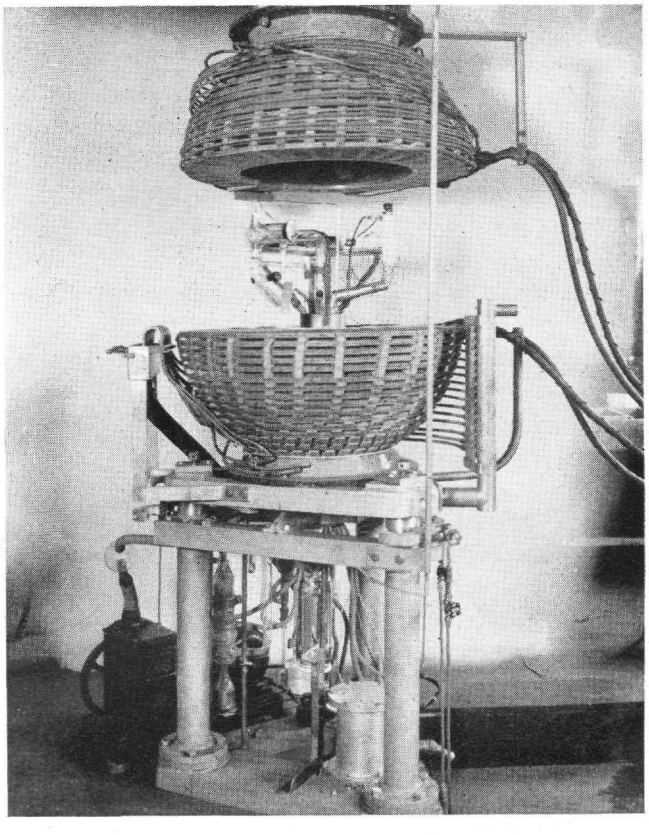

—Courtesy Westinghouse.

General View of Mass Spectrometer

Dr. John A. Hipple, with key part of the mass spectrometer.

—Courtesy Westinghouse.

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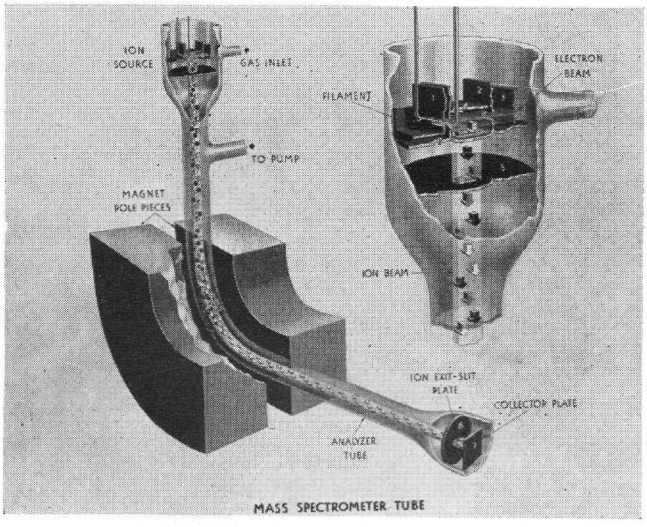
To make ions of a desired mass emerge from the magnetic field it is necessary to adjust the ion accelerating voltage V and the magnetic field H. When the fields are adjusted for ions of this mass, all other masses are deflected more or less than the specified ions and are lost on the grounded shield in the interior of the analyses. By simply adjusting either V or H or both any other mass desired may be focused on the exit slit and measured.

The modern spectrometer requires about 15kw and operates on 110 volts, 60 cycle power supply. The uses of the spectrometer include: (a) analyzing minute traces of gas in a mixture, (b) making analysis of a gas in a mixture, (c) providing a more complete and rapid analyzing of mixtures, (d) tracing stable isotopes, and (e) giving continuous indication of changing composition during a process such as the gas atmosphere in heat treating furnaces.

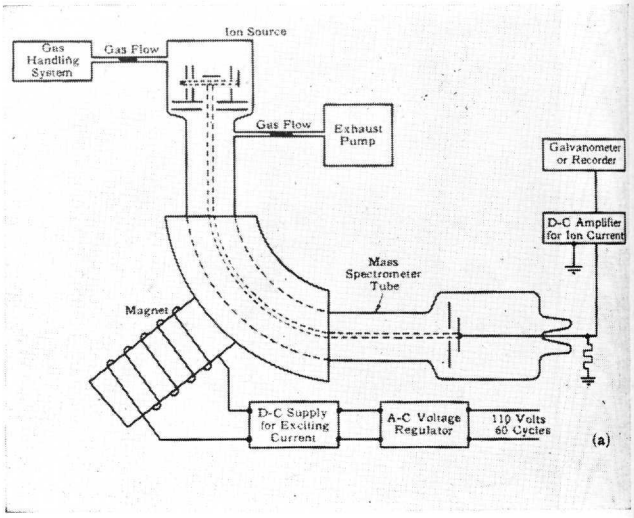
The spectrometer is used to a large extent for hydrocarbon analysis. It aids greatly here in discovering impurities of higher molecular weight than that of the main component since there is no longer the conflict in masses, and thus the impurities will stand out. The problem of hydrocarbon analysis is one which is important in aviation gasoline, synthetic rubber, and chemical industries.

It is easy to see the many advantages of the mass spectrometer. In 15 minutes the apparatus is able to dissect a complicated gas molecule at twenty-five-millionth of an inch long. Analyses such as this are not only slowly made by any other method but they are more inaccurate. Dr. Hipple estimates that the spectrometer



—Courtesy Westinghouse.

General View and Close-up of Ionizing Structure



—Courtesy Westinghouse.

Diagramatic View of Elements of Mass Spectrometer

is sensitive enough to detect one part in 100,000 of a substance under observation. Another important factor to take into account is that the spectrometer requires only a thimbleful of gas for each test, while butadiene plants chemists now have to draw off a bucketful of gas for involved procedure of breaking down the mixture by "fractionating" or distilling. The spectrometer is built in a portable cabinet thus making it possible to be moved from test to test. This electronic device is freeing hundreds of highly skilled chemists from tedious but important production testing in war plants. With all these things taken into account it can be plainly seen that the mass spectrometer has shed its disgiuse of a "gadget" and is rapidly becoming an indispensable part of war industry.